

NASA CR-

160325

(NASA-CR-160325) POWER EXTENSION PACKAGE
(PEP) SYSTEM DEFINITION EXTENSION, ORBITAL
SERVICE MODULE SYSTEMS ANALYSIS STUDY.
VOLUME 5: PEP ENVIRONMENTAL SPECIFICATION
(McDonnell-Douglas Astronautics Co.) 45 p

N79-33241

Unclas
G3/16 45821

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CORPORATION



POWER EXTENSION PACKAGE (PEP) SYSTEM DEFINITION EXTENSION

Orbital Service Module Systems Analysis Study

VOLUME 5
PEP Environmental Specification

AUGUST 1979

MDC G7870

NAS 9-15532

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A handwritten signature in cursive script, reading "D. C. Wensley", written over the printed name and title.

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PREFACE

The extension phase of the Orbital Service Module (OSM) Systems Analysis Study was conducted to further identify Power Extension Package (PEP) system concepts which would increase the electrical power and mission duration capabilities of the Shuttle Orbiter. Use of solar array power to supplement the Orbiter's fuel cell/cryogenic system will double the power available to payloads and more than triple the allowable mission duration, thus greatly improving the Orbiter's capability to support the payload needs of sortie missions (those in which the experiment remains in the Orbiter).

To establish the technical and programmatic basis for initiating hardware development, the PEP concept definition has been refined, and the performance capability and the mission utility of a reference design baseline have been examined in depth. Design requirements and support criteria specifications have been documented, and essential implementation plans have been prepared. Supporting trade studies and analyses have been completed.

The study report consists of 12 documents:

- Volume 1 Executive Summary
- Volume 2 PEP Preliminary Design Definition
- Volume 3 PEP Analysis and Tradeoffs
- Volume 4 PEP Functional Specification
- Volume 5 PEP Environmental Specification
- Volume 6 PEP Product Assurance
- Volume 7 PEP Logistics and Training Plan Requirements
- Volume 8 PEP Operations Support
- Volume 9 PEP Design, Development, and Test Plans
- Volume 10 PEP Project Plan
- Volume 11 PEP Cost, Schedules, and Work Breakdown Structure Dictionary
- Volume 12 PEP Data Item Descriptions

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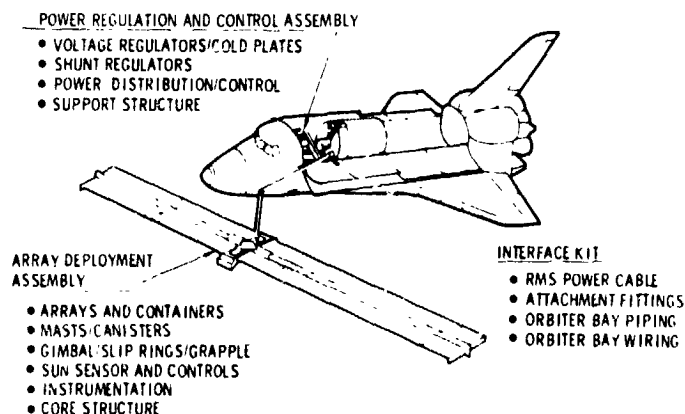
FOREWORD

The Power Extension Package (PEP) is a solar electrical power generating system to be used on the Shuttle Orbiter to augment its power capability and to conserve fuel cell cryogenic supplies, thereby increasing power available for payloads and allowing increased mission duration. The Orbiter, supplemented by PEP, can provide up to 15 kW continuous power to the payloads for missions of up to 48 days duration.


When required for a sortie mission, PEP is easily installed within the Orbiter cargo bay as a mission-dependent kit. When the operating orbit is reached, the PEP solar array package is deployed from the Orbiter by the remote manipulator system (RMS). The solar array is then extended and oriented toward the sun, which it tracks using an integral sun sensor/gimbal system. The power generated by the array is carried by cables on the RMS back into the cargo bay, where it is processed and distributed by PEP to the Orbiter load buses. After the mission is completed, the array is retracted and restowed within the Orbiter for earth return.

The figure below shows the PEP system, which consists of two major assemblies -- the Array Deployment Assembly (ADA) and the Power Regulation and Control Assembly (PRCA) -- plus the necessary interface kit. It is nominally installed at the forward end of the Orbiter bay above the Spacelab tunnel, but can be located anywhere within the cargo bay if necessary. The ADA, which is deployed, consists of two lightweight, foldable solar array wings with their containment boxes and deployment masts, two diode assembly interconnect boxes, a sun tracker/control/instrumentation assembly, a two-axis gimbal/slip ring assembly, and the RMS grapple fixture. All these items are mounted to a support structure that interfaces with the Orbiter. The PRCA, which remains in the Orbiter cargo bay, consists of six pulse-width-modulated voltage regulators mounted to three cold plates, three shunt regulators to protect the Orbiter buses from overvoltage, and a power distribution and control box, all mounted to a support beam that interfaces with the Orbiter.

PEP is compatible with all currently defined missions and payloads and imposes minimal weight and volume penalties on these missions. It can be installed and removed as needed at the launch site within the normal Orbiter turnaround cycle.



REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

MATERIAL	CONTRACT NO.	MCDONNELL DOUGLAS ASTRONAUTICS CO. HUNTINGTON BEACH, CALIF.	
	ORIGINAL DATE OF DRAWING	MCDONNELL DOUGLAS 	
	79-06-21		
	FIRST RELEASE OF PRINTS	ENVIRONMENTAL SPECIFICATION -	
		POWER EXTENSION PACKAGE - ORBITER	
ODD DASH NUMBERS SHOWN	PREPARED W.G. Nelson	SIZE	CODE IDENT NO.
EVEN DASH NUMBERS OPPOSITE	APPROVED	A	18355
PART OR IDENT NO.	CHECKED	DRAWING NO.	1023452
	DESIGN ACTIVITY APPROVAL		
FOR USAGE DATA SEE	CUSTOMER APPROVA	SCALE	SHEET 1 OF
ENGINEERING RECORDS			

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Section 1
INTRODUCTION

This specification establishes the natural and induced environments that the Power Extension Package (PEP) and GSE may be exposed to during ground operations and space operations with the Shuttle System. Space induced environments are applicable at the Orbiter attach point interface location. Attenuation or amplification of the environment by cradle or carrier structure between the Orbiter attachment and individual PEP components are not accounted for. The Orbiter provides an induced environment as benign or more benign than existing launch vehicles.

All probable environments are systematically listed according to each ground and mission phase.

Section 2
DOCUMENTATION

The following documents form a part of this specification to the extent specified herein. In the event of conflict between this document and other documents involved herein, the contents of this specification shall govern.

JSC 07700, Volume X	Natural Environment Design
Appendix 10.10	Requirements
NASA TMX 64757	Terrestrial Environment (Climatic) Criteria Guidelines for use in Aerospace Vehicle Development, 1973 Revision
NASA TN D-4404	An Analysis of Energetic Space Radiation and Dose Rates
NASA TMS 53957	Space Environment Criteria Guideline for Use in Space Vehicle Development
TMS 64668	Natural Environment Design Requirements for the Sortie Module
JSC 07636	Space Shuttle Program Lightning Protection Criteria Document
MIL-STD-810E	Environmental Test Methods

Section 3

NATURAL ENVIRONMENTS

The following are the natural environmental conditions to which PEP equipment and GSE may be exposed during its useful lifetime and must be considered in the design. These conditions are expressed in terms of parameters which are generally defined at extreme levels.

The extreme natural (ambient) environments which follow were selected or derived from data presented in Appendix 10.10, "Natural Environment Design Requirements," JSC 07700, Volume X, and in NASA TMS 64757, "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 1973 Revision" and in NASA TM D-4404, "An Analysis of Energetic Space Radiation and Dose Rates" February 1968.

If so desired, the PEP equipment may be protected during delivery to the launch and recovery operation by use of appropriate site facilities so that it is protected from the environment. Since a limited number of units are involved, relaxation of these requirements are allowable contingent upon an appropriate shipping or storage plan.

3.1 GROUND NATURAL ENVIRONMENTS

3.1.1 Transportation (Packaged)

The PEP system shall be capable of meeting the operating performance requirements specified herein after exposure to the following transportation conditions when packaged.

A. Air

1. Temperature Minus 65° to plus 150°F for 6 hours;
 190°F maximum for 1 hour.
2. Pressure Maximum of 15.23 pounds per square inch
 absolute (psia) sea level, minimum of
 3.28 psia (35,000 feet).

- | | | |
|----|-------------|---|
| 3. | Humidity | 0 to 100 percent relative humidity. |
| B. | Ground | |
| 1. | Temperature | Minus 40° to plus 122°F (ambient); plus 150° for 6 hours; 190°F for one hour. |
| 2. | Pressure | Maximum of 15.23 psia (sea level) minimum of 9.76 psia (10,000 feet). |
| 3. | Humidity | 8 to 100 percent relative humidity. |
| C. | Shock | As specified in FED-STD-101, Method 5019. |
| D. | Vibration | As specified in FED-STD-101, Method 5020. |

3.1.2 Storage

The PEP system shall be capable of meeting the operating performance requirements specified herein after exposure to the following storage conditions.

Environments specified are for Shuttle operational sites only.

- | | | |
|----|---|---|
| A. | Sheltered uncontrolled environment (packaged or unpackaged) | |
| 1. | Temperature | Minus 23° to plus 150°F. |
| 2. | Humidity | 8 to 100 percent relative humidity. |
| 3. | Pressure | Maximum of 15.23 psia (sea level), minimum of 12.4 psia. |
| 4. | Ozone | Surface maximum* 3 to 6 parts per hundred million (pphm). |
| 5. | Fungus | As specified in MIL-STD-810E. |
| 6. | Sand and dust | As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 grams per cubic foot. |
| B. | Unsheltered equipment (packaged) | |
| 1. | Temperature | Minus 23° to plus 115°F. |
| 2. | Pressure | Maximum of 15.23 psia (sea level), minimum of 12.4 psia. |
| 3. | Humidity | 8 to 100 percent relative humidity. |
| 4. | Sand and dust | Extreme design surface values as follows.
Sand particle diameter* |

inches 0.0031 to 0.039

*NOTE: 90 percent or more between 0.0031 and 0.012 inches.

Sandstorm suspended sand,

pcf 1.2

Sandstorm wind speed,

ft/sec 33

Sand particle hardness,

Moh. scale 7 to 8

Dust particle 0.0000039 to

diameter** 0.0031 inches
inches

Dust storm wind 33

speed ft/sec

Dust storm verticle Uniform to

distribution 656 ft.

Dust particle hardness,

Moh. scale 7 to 8

5. Hail and snow

Design for extreme hail at surface
characteristics as follows:

Maximum hailstorm diameter,

inches 2

Duration, minutes ≤ 15

Fall velocity,

ft/sec 100

Hailstorm density,

pcf 50

Wind speed,

ft/sec 33

Hail hardness,

Moh. scale 2 to 4

Maximum depth,

inches 2

Occurrence Once in 15 years

frequency

***NOTE: 9 percent or more between 0.0000039 and 0.0000079 inches.

Design extreme surface snow characteristics as follows:

Maximum snow load of 10.2 psf.

- | | |
|--------------------|--|
| 6. Salt fog | Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt (NaCl) solution by weight for 30 days. |
| 7. Rain | Maximum of 19 inches in 24 hour period including short period extremes of four inches for one hour. |
| 8. Ozone | Surface maximum* 3 to 6 parts per hundred million (phm); 35,000 feet maximum 100 phm. |
| 9. Solar radiation | Solar radiation of 377.6 British thermal unit (Btu)/ft ² hour total normal incident. |
| 10. Fungus | As specified in MIL-STD-810E. |

3.1.3 Ground Handling Loads (Unpackaged)

The following are the ground handling loads for unpackaged hardware.

- A. Handling shock - Bench handling shock as specified in MIL-STD-810, Method 516.1, Procedure V.
- B. Design shock - As specified in MIL-STD-810, Method 516.1, Procedure I.
- C. Acceleration (hoisting loads) - Land: 2 g vertical within a plus or minus cone angle of 20 degrees. Water: 2.67 g vertical within a plus or minus cone angle of 20 degrees.

3.1.4 Launch Site Operations Environment

This section describes the environments (atmosphere temperature, pressure, humidity, and contamination) to which PEP equipment may be subjected during integration, installation, and prelaunch checkout activities.

*NOTE: Total oxidant concentrations may infrequently reach 60 phm for periods of 1 to 3 hours during a 24-hour period.

3.1.4.1 Integration Operations

A. Operation and Checkout Building (O&C)

1. Temperature $21^{\circ} \pm 3^{\circ}\text{C}$ ($70^{\circ} \pm 5^{\circ}\text{F}$)
2. Humidity $50 \pm 5\%$ RH
3. Pressure 12.4 to 15.23 psia
4. Cleanliness Class 100 000

B. Orbiter Processing Facility (OPF) - The area assigned for payload processing and checkout will provide the following conditions:

1. Temperature $24 \pm 1^{\circ}\text{C}$ ($75^{\circ} \pm 3^{\circ}\text{F}$)
2. Humidity $50\% \text{ RH} \pm 5\%$
3. Pressure 12.4 to 15.23 psia
4. Cleanliness Purged with Class 100 000 air

3.1.4.2 Orbiter Cargo Bay

While the PEF flight unit is installed in the Orbiter cargo bay and the cargo bay doors are closed, the Orbiter cargo bay atmosphere will be controlled to provide the following conditions.

Air purge - ground transport, VAB and OPF

1. Flow rate: 0 to 94 lbs/min.
2. Temperature: Selectable within the range of $65-85^{\circ}\text{F}$ controlled to $\pm 2^{\circ}\text{F}$ of the desired setting.
3. Cleanliness: Nominally class 100 guaranteed class 5000 (HEPA filtered) air with 17 ppm or less hydrocarbons based on methane equivalent.
4. Humidity: Equal to or less than 50 percent relative humidity.

Prior to the cargo bay doors being closed, the cargo bay environment will be maintained by providing a facility purge of:

1. Temperature: $70 \pm 5^{\circ}\text{F}$
2. Cleanliness: Nominally class 100 guaranteed class 5000 (HEPA filtered).
3. Humidity: $45 \pm 5\%$ RH

3.2 SPACE NATURAL ENVIRONMENTS

Space is normally considered to be altitudes greater than 48.6 n.m.i., (295,000 ft., 90 Km).

3.2.1 Pressure

1×10^{-10} Torr. (1.3×10^{-8} n/m²) shall be the design consideration. Other values are as follows:

Altitude	Max. P. Torr. (n/m ²)	Min. P. Torr. (n/m ²)
70 n.mi. (129.7 km)	1.4×10^{-5} (1.87×10^{-3})	8×10^{-6} (1.07×10^{-3})
100 n.mi. (185.3 km)	2.2×10^{-6} ($.29 \times 10^{-3}$)	4.7×10^{-7} ($.063 \times 10^{-3}$)
500 n.mi. (926.5 km)	2.2×10^{-9} (29.33×10^{-8})	4.7×10^{-11} ($.63 \times 10^{-8}$)
1200 n.mi. (2223.6 km)	Approx. 1×10^{-11} (.13 $\times 10^{-8}$)	Same as maximum

Highest pressure at orbital altitudes would be the maximum pressure at lowest orbital altitude 70 n.mi. (129.7 km) and lowest pressure at orbital altitudes would be the minimum pressure at the highest orbital altitude 1200 n.mi (2223.6 km).

3.2.2 Solar Radiation (Thermal)

Temperature extremes for items exposed to space environments cannot be categorically defined. When determining these extremes analytically, use the following data:

Environmental Parameter	Design Value
Solar radiation	443.7 Btu/Ft ² /hr (1398.76 w/m^2)
Earth albedo	30 percent
Earth radiation	77 Btu/Ft ² /hr (242.74 w/m^2)
Space sink temperature	0° Rankin (0° Kelvin)

3.2.3 Solar Radiation Ionizing

The natural radiation environment in terrestrial space consists of (1) galactic cosmic radiation, (2) geomagnetically trapped radiation, and (3) solar flare particle events.

3.2.3.1 Galactic Cosmic Radiation (Mainly Protons)

Composition: 85% protons, 13% alpha particles, 2% heavier nuclei
Energy Range: 10^8 to 10^{19} electron volts; predominant 10^9 to 10^{13} electron volts.

Flux Outside Earth's Magnetic Field: 0.2 to 0.4 particles/CM²/steradian/sec

Integrated Yearly Dose: Approximately 4 to 10 rads.

3.2.3.2 Geomagnetically Trapped Radiation (Proton, Electron)

Energy: Electron - Up to several MeV Proton - Up to several 100 MeV

Flux: Electron - Up to 10^8 Electrons/cm²/sec >0.5 MeV Proton - Up to 10^5 Protons/cm²/sec >30.9 MeV

See NASA TN D-4404 for specific mission radiation environments and resulting exposure/shielding relationships.

3.2.3.3 Solar Particle Events

Composition: Protons and alpha particles

Occurrence: Sporadically and lasting for several days

Particle Event Model (free space): See Section 2.4.3 of NASA TMX 64627

$$\begin{aligned} \text{Protons: } N_p(>T) = & \begin{array}{ll} 7.25 \times 10^{11} T^{-1.2} & 1 \text{ MeV} \leq T \leq 10 \text{ MeV} \\ 3.54 \times 10^{11} e^{-F(T)/73} & 10 \text{ MeV} \leq 30 \text{ MeV} \\ 2.64 \times 10^{11} e^{-F(T)/73} & T > 30 \text{ MeV} \end{array} \end{aligned}$$

$$\begin{aligned} \text{Alphas: } N_\alpha(>T) = & \begin{array}{ll} N_p(>T) & T < 30 \text{ MeV} \\ 7.07 \times 10^{12} T^{-2.14} & T \geq 30 \text{ MeV} \end{array} \end{aligned}$$

Where $N_p(>T)$, $N_\alpha(>T)$ = Protons/cm², Alphas/cm² with energy >T in MeV

$F(T)$ = Particle magnetic rigidity in mV given by

$$F(T) = 1/Z_e T (T + 2M_0 C^2)$$

Z_e is particle charge in units of electron charge; i.e.,

$$Z_e = 1 \text{ for Protons; and } 2 \text{ for Alphas}$$

$$M_0 C^2 = 938 \text{ MeV for Protons, } 3728 \text{ MeV for Alphas}$$

For near-earth orbital altitudes, the above free-space event model must be modified since the earth's magnetic field deflects some of the low-energy particles that would enter the atmosphere at low latitudes to the poles. While in near earth polar exposure from solar particle events will be approximately 30% of that of free space. Relative exposure decreases rapidly with decreasing orbital inclination.

3.2.4 Meteoroids

The meteoroid model encompasses particles of cometary origin in the mass range between 1 and 10^{-12} grams for sporadic meteoroids and 1 to 10^{-6} grams for stream meteoroids.

Average total environment:

Particle density 0.5 g/cm^3

Particle velocity 20 km/sec

(1) For $10^{-6} \leq m \leq 10^0$ $\log_{10} N_t = 14.37 - 1.213 \log_{10} m$

(2) For $10^{-12} \leq m \leq 10^{-6}$ $\log_{10} N_t = 14.339 - 1.584 \log_{10} m$
 $- 0.063 (\log_{10} m)^2$

N_t = - no. particles/ m^2/sec of mass m or greater

m = mass in grams

Defocusing factor for earth, and if applicable, shielding factor are to be applied.

Section 4
INDUCED ENVIRONMENT

The following induced environment exists in the payload bay.

4.1 THERMAL ENVIRONMENT

4.1.1 Payload Bay Wall Temperature

The temperature range at the payload bay walls are defined in Table 4.1-1. The maximum temperature for the radiator when the doors are closed shall be 184°F.

Table 4.1-1. Payload Bay Wall Temperature

	Condition	Minimum	Maximum
1.	Prelaunch	+40°F (4.4°C)	+120°F (48.9°C)
2.	Launch	+40°F (4.4°C)	+150°F (65.6°C)
3.	On-orbit (doors open)	-250°F (-156.7°C)	+200°F (93.3°C)
4.	Entry and post-landing	-50°F (-45.6°C)	+200°F (93.3°C)

Conditions 1 and 2 are for an assumed adiabatic payload.

Condition 3 is for an assumed empty cargo bay.

Condition 4 is for an assumed adiabatic payload. The maximum temperature is for an assumed initial 70°F cargo bay wall temperature. The minimum temperature is for an assumed initial -250°F cargo bay wall temperature. Local areas around the vents may reach 225°F for duration of less than 2 minutes after vents are opened.

4.1.2 Entry Air Inlet Temperature

For design purposes, the worst case temperature of air entering the payload bay during entry shall be assumed to be as defined in Figure 4.1-1.

4.2 LIMIT-LOAD FACTORS/ANGULAR ACCELERATIONS

The load factors/angular accelerations specified in Tables 4.2-1, 2, and 3 are appropriate for preliminary design of PEP primary structure and for determination of preliminary Orbiter/PEP interface loads as the guiding criteria only.

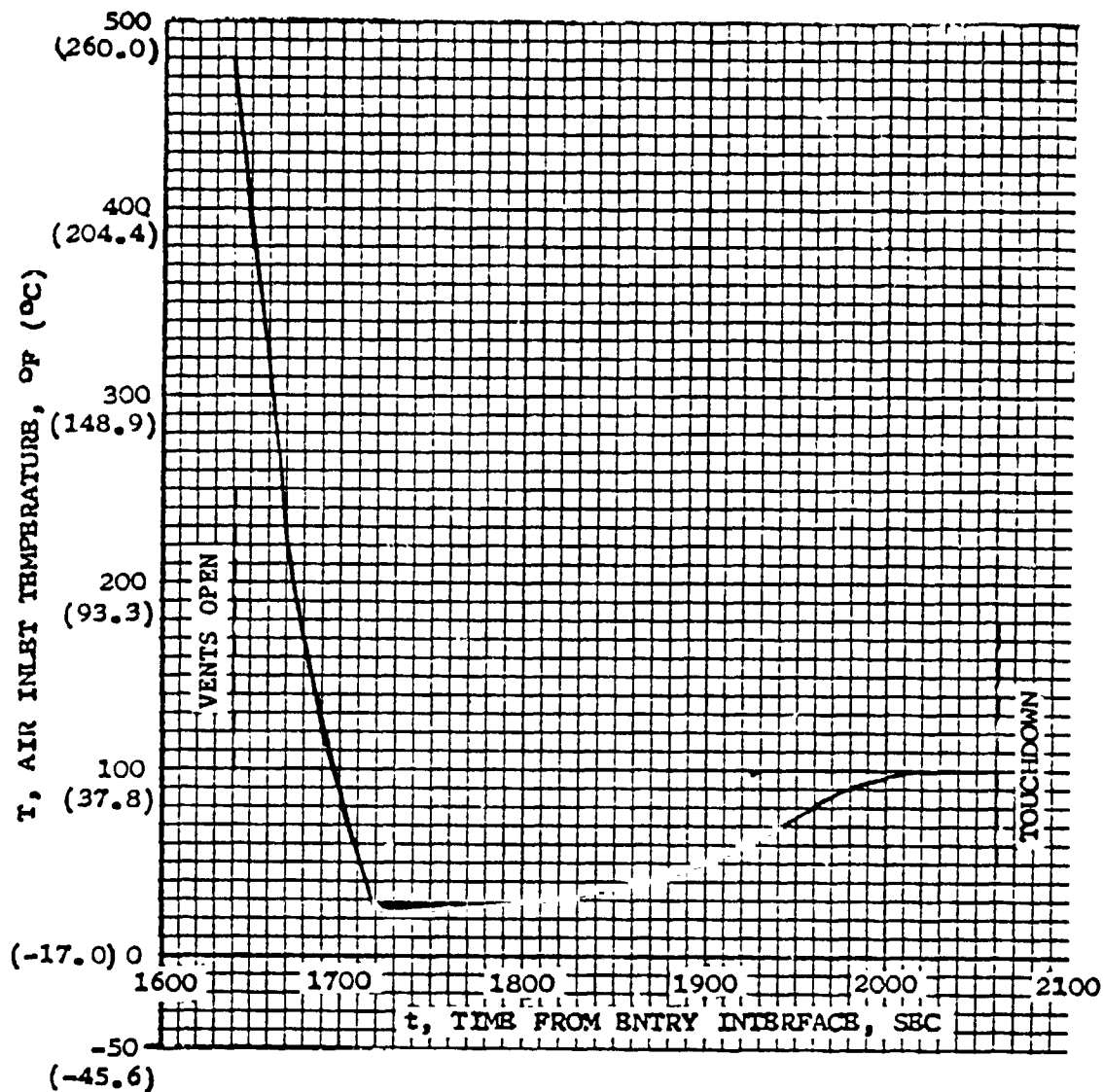


Figure 4.1-1. Air Temperature Entering the Payload Bay During Entry – Max Air Temperature Case

The center-of-rotation for angular accelerations is at the PEP element center-of-gravity. The load factors/angular accelerations for emergency landing condition are defined in Paragraph 4.2.3.

PEP load factor/angular acceleration is defined as the total externally applied force/moment on the PEP or PEP component divided by the corresponding total or component weight/mass moment of inertia and carries the sign of the externally applied force/moment in accordance with the Orbiter coordinate system. (See Figure 4.2-1.)

Table 4.2-1 Cargo Limit-Load Factors/Angular Accelerations For Preliminary Design (Quasi-Steady Flight Events)

FLIGHT EVENT	LOAD FACTOR g			ANGULAR ACCELERATION RAD/SEC ²			CARGO WEIGHT
	Nx	Ny	Nz	$\ddot{\psi}$	$\ddot{\theta}$	$\ddot{\varphi}$	
<u>ASCENT</u>							Up to 65 Klb (29484 kg)
HIGH-Q BOOST ENVELOPE	-1.9	±0.40	- 0.25 -0.50 -	±0.10	±0.15	±0.15	
INTEGRATED VEHICLE BOOST MAX Nx	-2.9	±0.06	-0.10	±0.20	±0.25	±0.25	
ORBITER BOOST MAX Nx	-3.17	0.0	-0.60	±0.20	±0.25	±0.25	
POST SRB STAGING	-1.10	±0.12	-0.59				
<u>DESCENT</u>							Up to 32 Klb (14515 kg)
TAEM: PITCH MANEUVER	- 1.01 -0.15 - 0.25 - 0.97 0 -	0	2.50	0	0	0	
		0	2.50	0	-0.11	0	
		0	-1.00	0	0	0	
TAEM: ROLL MANEUVER	0.65	±0.12	1.98	±1.28	0.02	±0.13	
TAEM: YAW MANEUVER	0.90	±1.25	1.0	0.0	0.0	0.0	
	0.03	±1.24	1.0	0.0	0.0	±0.12	

Table 4.2-2 Cargo Limit-Load Factors/Angular Accelerations For Preliminary Design (Transient Flight Events)

FLIGHT EVENT	LOAD FACTOR g			ACCELERATION RAD/SEC ²			CARGO WEIGHT
	Nx	Ny	Nz	$\ddot{\phi}$	$\ddot{\theta}$	$\ddot{\psi}$	
<u>ASCENT</u>							
LIFT-OFF	-0.2 -3.2	1.0 -1.0	2.5 -2.5	0.1 -0.1	0.15 -0.15	0.15 -0.15	Up to 65 Klb (29484 kg)
<u>DESCENT</u>							
LANDING	1.8 -2.0	±1.0 ±1.0	4.2 -0.3	±0.25 ±0.25	1.25 -0.75	±0.30 ±0.30	Up to 32 Klb (14515 kg)

Table 4.2-3 Emergency Landing Design Load Factors

	Load Factor 65 Klb (29484 kg) Up 32 Klb (14515 kg) Down		
CONDITION	X	Y	Z
Emergency Landing (Outside Crew Compartment)	+4.5 -1.5	+1.50 -1.50	+4.5 -2.0

Sign convention follows that of the Orbiter coordinate system in Figure 4.2-1.

Emergency landing load factors are ultimate. The longitudinal load factors are directed in all aftward azimuths within a cone of 20 degrees half-angle. The specified load factors shall operate separately.

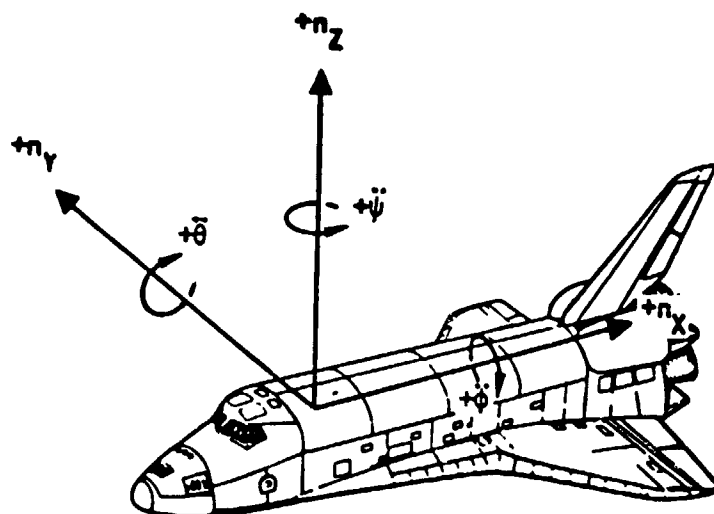


Figure 4.2-1. Sign Convention for Cargo Limit-Load Factors/Angular Accelerations

These load factors/angular accelerations are valid for any location in the bay. The load factors/angular accelerations result from the response of the Shuttle vehicle structure, including cargo, to external forces corresponding to both quasi-static and transient flight events. These external forces are generated by the thrust, aerodynamics, wind shear, prelaunch restraints, entry maneuvers, landing gear impact, etc.

Accelerations at specific points within the PEP will depend upon PEP design characteristics and mounting methods. Portions of the PEP that are cantilevered from their support points, or that have substantial internal flexibility, may experience higher accelerations than those reflected in the tables.

The load factors/angular accelerations shall be considered in all combinations for each event.

4.2.1 Quasi-Steady Flight Events

The load factors/angular accelerations associated with the quasi-steady flight events are generated by external forces which change slowly with time and for which the vehicle elastic responses are relatively small. Consequently, coupled transient dynamic analyses are not normally required. However, for PEP with redundant Orbiter interfaces, a coupled static analysis of the various quasi-static flight events shall be used for determining deflections and PEP interface forces. Shuttle model and deflection data to analyze quasi-static flight events shall be included in the payload-unique ICD.

Load factors and angular accelerations are specified in Table 4.2-1 for quasi-steady flight events during ascent and descent, for up to a maximum of 65,000 lb. (29,484 kg) lift-off cargo and up to maximum of 32,000 lb. (14,515 kg) landed cargo. These conditions are normal design conditions for the Orbiter structure.

4.2.2 Transient Flight Events

The transient flight events correspond to conditions for which the external forces are highly transient in nature and significant elastic response occurs. Shuttle lift-off and landing are events of this type. The associated PEP responses depend on the PEP geometry, stiffness, and mass characteristics. Consequently, design values of PEP/Shuttle interface forces and PEP design loads shall be determined by coupled transient analysis. However, typical load factors for the transient events are given in Table 4.2-2.

The load conditions in Table 4.2-2 are for an ascent cargo weight of up to a maximum of 65,000 lb. (29,484 kg) lift-off cargo and up to a maximum of 32,000 lb. (14,515 kg) landing cargo. The maximum symmetric design landing sink speed is 9.6 fps (2.93 mps).

4.2.3 Emergency Landing Load Factors

The Orbiter vehicle design considers safe crew egress following emergency landing or water ditching. Hence, the mounting structures for equipment and crew provisions vessels shall be designed to load factors equal to or greater than those shown in Table 4.2-2. Equipment inside the Orbiter crew compartment shall be designed to preclude hazards to the flight personnel after the application of the emergency landing loads defined in the table. The attachment

structures (including fittings and fasteners) must be designed for emergency landing loads. The attachment structure equipment where failures could result in injury to personnel or prevent egress from the emergency landed vehicle must be designed for this requirement. Equipment design shall consider provisions to maximize the probability of safe crew egress following an emergency landing.

4.3 ACOUSTICS

The spatially averaged acoustic levels in an empty payload bay shall not exceed those defined in Table 4.3-1. The acoustic levels during orbit, entry and landing are significantly below the ascent levels and shall be assumed to be negligible.

Acoustic levels for specific payload bay equipment are dependent on geometry, surface area and acoustic absorption characteristics and will differ from those of the empty payload bay.

4.4 VIBRATION

The random vibration environments predicted for the unloaded mid-fuselage main longeron payload trunnion fitting and the unloaded mid-fuselage keel trunnion fitting are shown, respectively, in Figures 4.4-1 and 4.4-2. These empty payload bay environments will be reduced by the presence of equipment. The unloaded attach point vibration environments may be adjusted to account for the presence of a payload by use of the 3-step procedure exemplified in Appendix I, Paragraph I.4 of ICD 2-19001, Shuttle Orbiter/Cargo Standard Interfaces, Revision F.

4.5 ON-ORBIT ACCELERATIONS

During normal Orbiter attitude keeping activities, thrusting of the Orbiter RCS shall cause slight accelerations to be exerted on STS element equipment depending on the location with respect to the center-of-rotation.

RCS and vernier thrust values shall be as defined in Table 4.5-1. All three angular accelerations may occur simultaneously and the linear acceleration at any point in the STS element system shall be calculated based on the distance from the vehicle center-of-rotation. This location shall vary to some extent with the particular payload weight distribution but shall be in the vicinity of X_o 1080, Y_o 0, and Z_o 400, for typical missions.

Table 4.3-1 Orbiter Cargo Bay Internal Acoustic Noise

1/3 Octave Band Center Frequency (Hz)	Sound Pressure * Level (dB) ref. $2 \times 10^{-5} \text{N/m}^2$ Lift-Off 5 Seconds/Mission	Sound Pressure Level (dB) ref. $2 \times 10^{-5} \text{N/m}^2$ Aeronoise 5 Seconds/Mission
31.5	122.0	112.0
40.0	124.0	114.0
50.0	126.0	116.0
63.0	127.5	118.0
80.0	129.5	120.0
100.0	130.5	122.0
125.0	132.0	124.0
160.0	133.0	125.0
200.0	133.5	126.5
250.0	134.0	127.0
320.0	134.5	127.0
400.0	134.5	127.0
500.0	134.0	127.0
630.0	133.5	125.0
800.0	133.0	123.0
1,000.0	132.0	119.0
1,250.0	131.5	118.0
1,600.0	130.0	117.0
2,000.0	129.0	115.0
2,500.0	128.0	113.0
3,200.0	126.5	111.0
4,000.0	125.0	109.0
5,000.0	124.0	107.0
6,300.0	122.5	105.0
8,000.0	121.0	102.0
10,000.0	120.0	101.0
OAL	145.0	137.0

*Development testing to confirm the internal payload bay acoustic environment has been completed with potential reductions in acoustic levels for portions of the spectra. Additional confirmation of payload bay acoustic levels and changes to the 145 dB OA environment are not expected before first Orbital flight; however, if specific hardware development problems are encountered which can be affected by incorporation of the development test results, the JSC Space Shuttle Program Office is to be contacted for additional consultation.

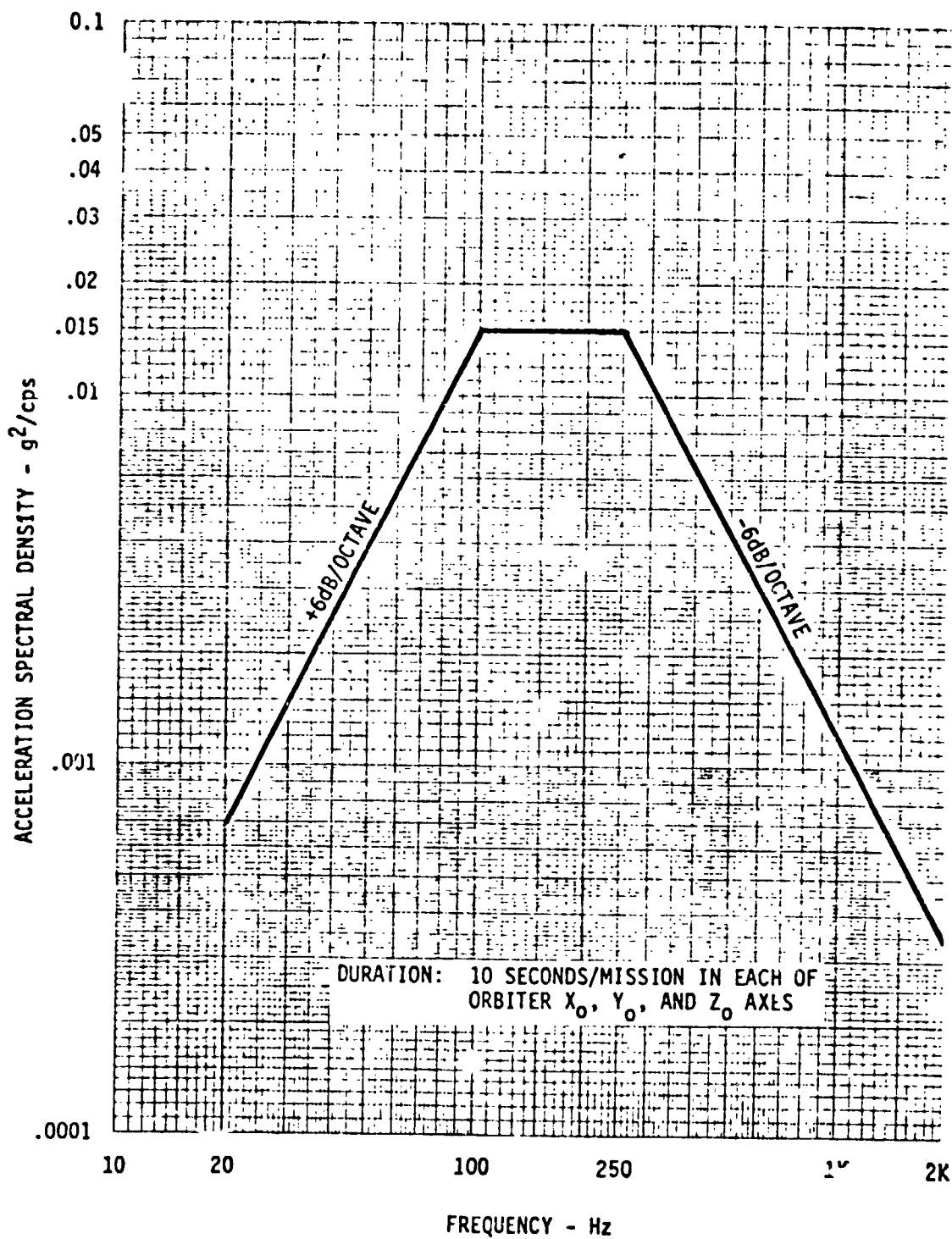


Figure 4.4-1. Unloaded Main Longeron Trunnion Fitting Vibration

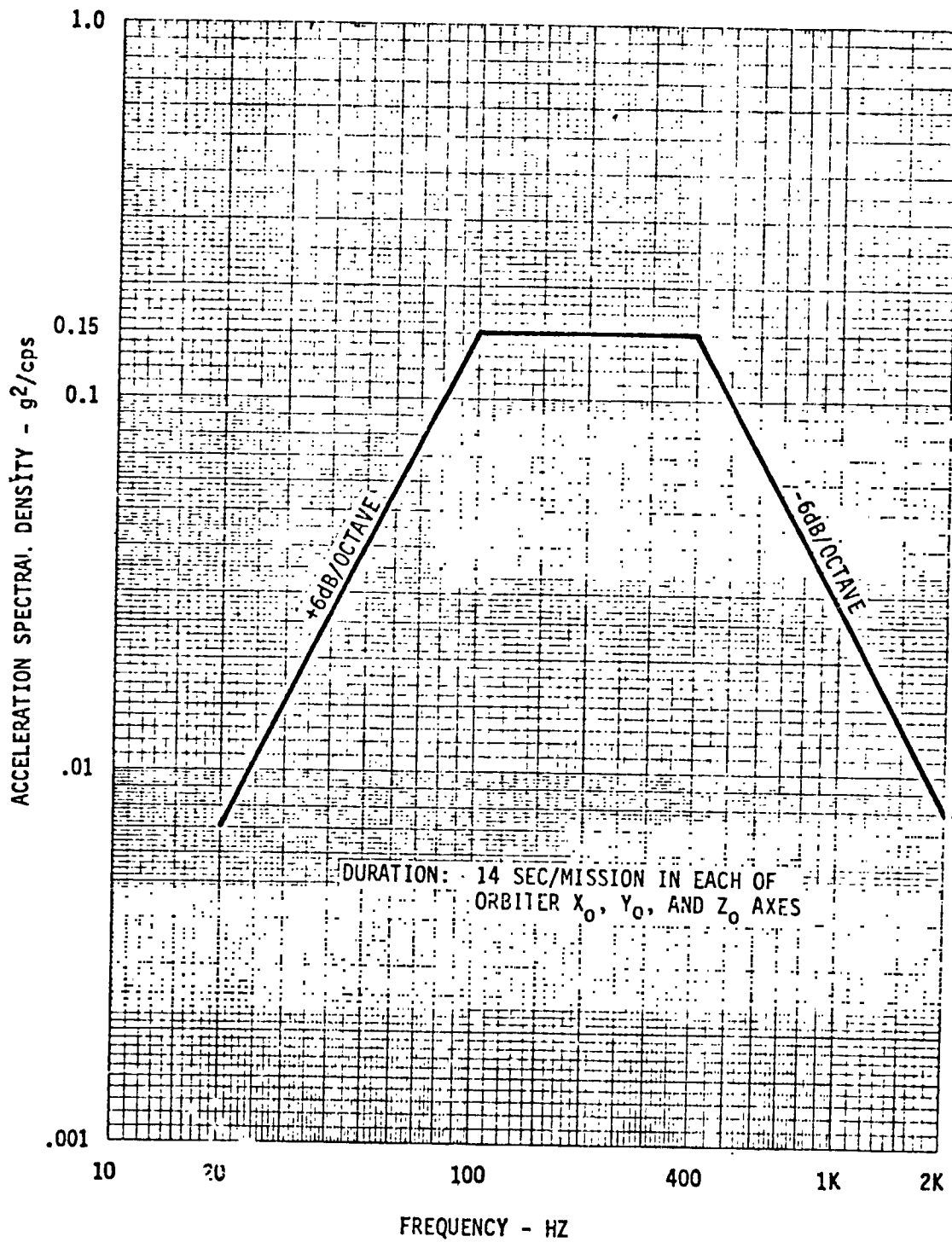


Figure 4.4-2. Unloaded Keel Trunnion Fitting Vibration

Table 4.5-1. ORBITER RCS MAXIMUM ACCELERATION LEVELS

System	Max Translational * Accelerations Ft/Sec ²					Max Rotational * Accelerations Deg/sec ²			
	-X	+X	±Y	-Z	+Z	±Roll	±Pitch	-Pitch	±Yaw
RCS (870 lbs)	0.6	0.5	0.7	1.3	1.1	1.2	1.4	1.5	0.8
Verniers (25 lbs)	0.0	0.0	0.007	0.0	0.008	0.04	0.03	0.02	0.02

*Assumes 170 Klb Orbiter and 32 Klb payload. 65 Klb payload (TBD).

4.6 ORBITER/CARGO BAY PARTICULATES AND GASES ENVIRONMENT

4.6.1 Purge Gas in the Cargo Bay

4.6.1.1 Lift-Off Through Orbit Insertion

Purge gas shall be residue remaining from purge prior to lift-off. Nominal cargo bay pressure decay shall be assumed to be that shown in Figure 4.6-1.

4.6.1.2 Entry and Descent

Atmospheric air filtered through 35-micron glass-bead-rating filters shall be used to repressurize the cargo bay. Nominal cargo bay repressurization shall be assumed to be that shown in Figure 4.6-2.

4.6.2 Contamination

Payload bay contamination will be minimal by selection of materials with low outgassing characteristics. Material selection criteria of 1 percent, or less, total mass loss and 0.1 percent, or less, Volatile Condensable Material (VCM) as defined in NASA/JSC Specification SP-R-0022, or its equivalent, shall be used.

Contamination outside the bay will be to a level which shall limit contamination to cargo, payload bay, Orbiter windows, optical surfaces and Orbiter thermal protection system. Dump design shall be time-selectable in order to program occurrences to be compatible with other mission operations.

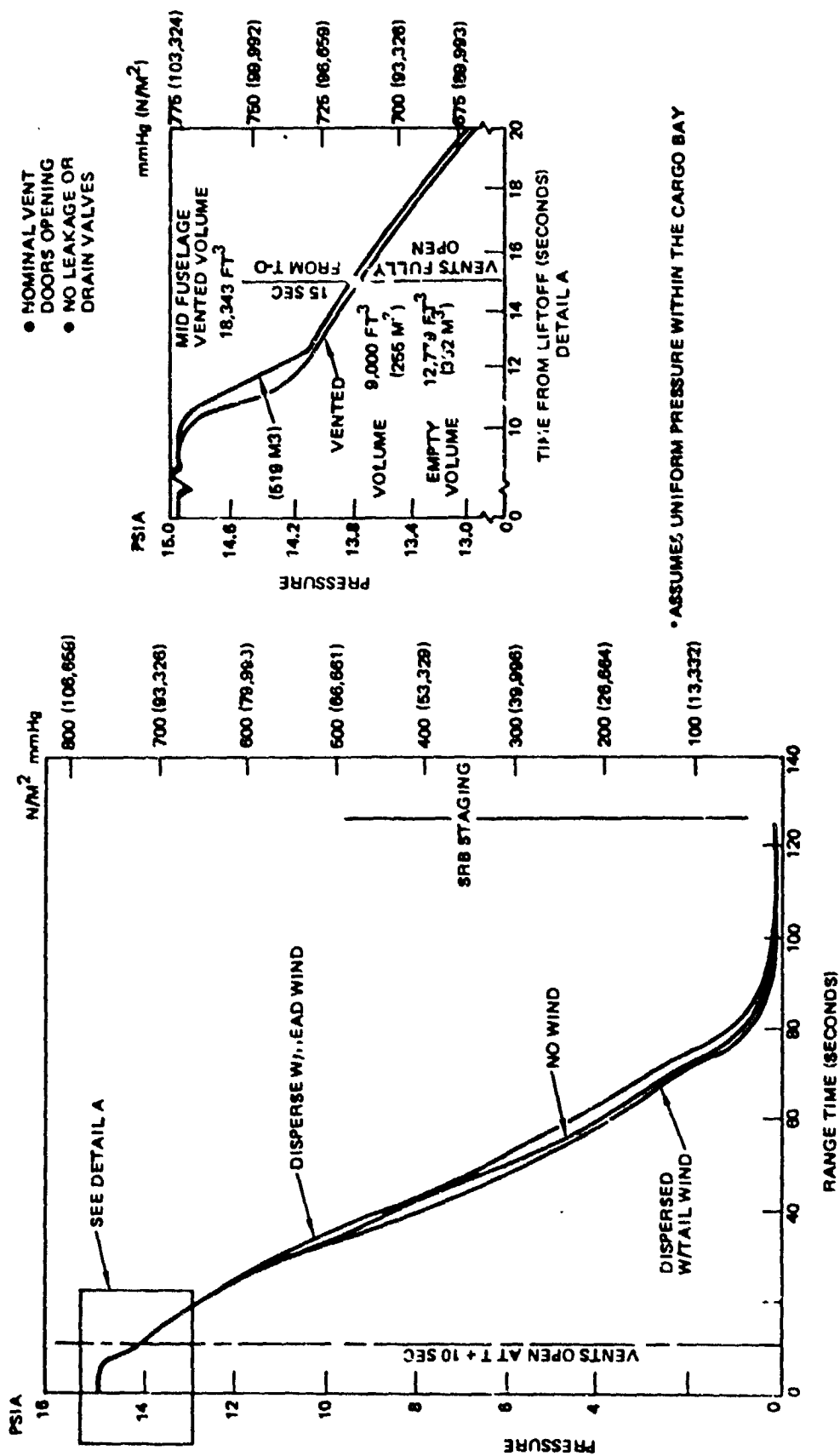


Figure 4.6-1. Orbiter Cargo Bay Internal Pressure* Histories During Ascent

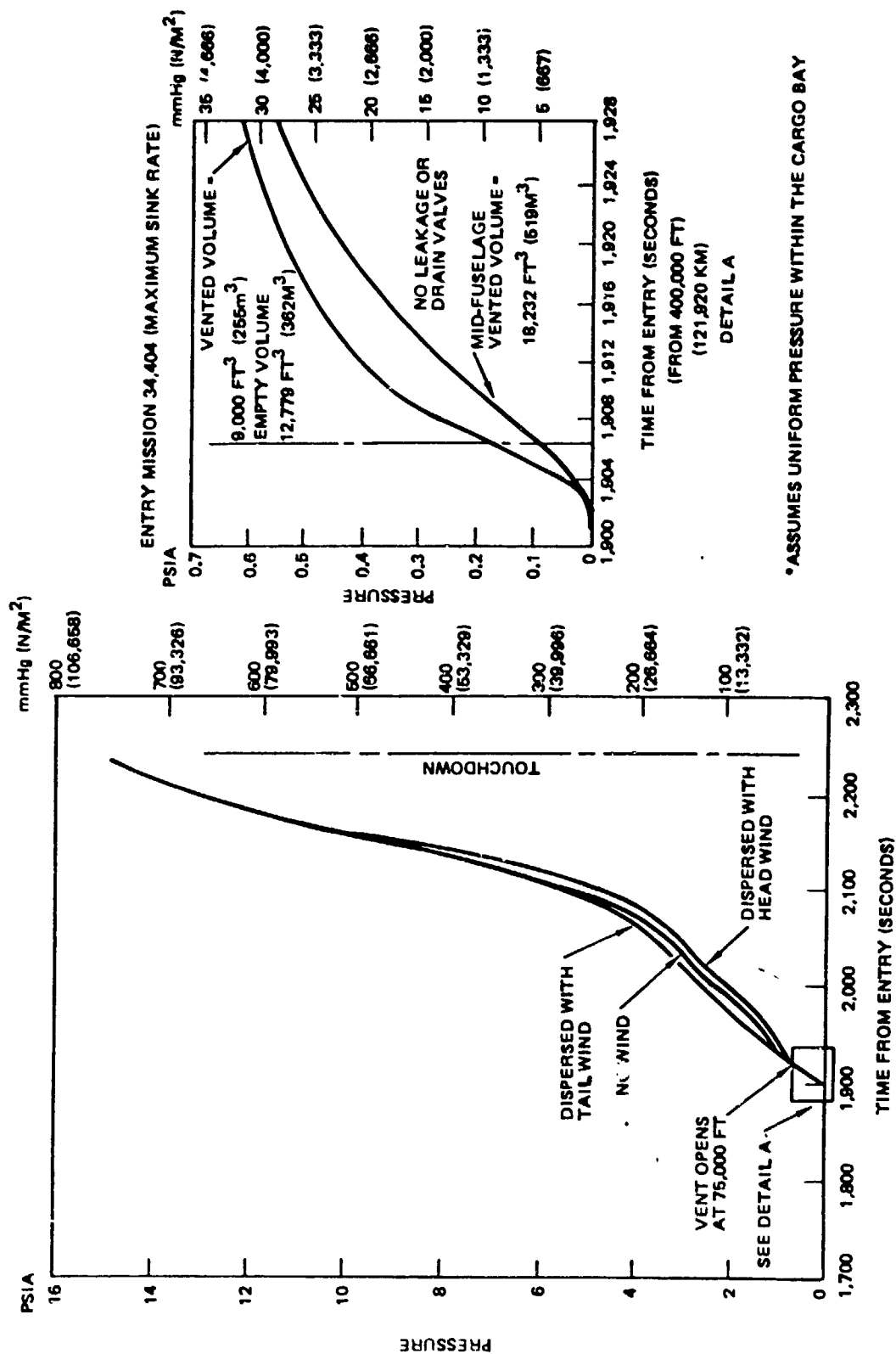


Figure 4.6-2 Orbiter Cargo Bay Internal Pressure* History During Entry

4.7 ELECTROMAGNETIC INTERFERENCE ENVIRONMENT

4.7.1 Shuttle-Produced Interference Environment

The Shuttle-produced conducted and radiated interference is limited to the levels indicated in Paragraphs 4.7.1.1 and 4.7.1.2.

4.7.1.1 Conducted Interference

The conducted interference produced by the Shuttle applicable to all DC and AC interfaces shall be limited as follows:

A. In-Flight DC Power Bus Ripple: The in-flight DC power bus ripple at the interface shall not exceed:

1. ± 0.9 volts peak-to-peak narrowband (30 Hz to 7 KHz) falling 10 dB per decade to 0.28 volts peak-to-peak to 70 KHz, thereafter remaining constant to 400 MHz.

2. ± 0.8 volts peak broadband in the frequency band from 30 Hz to 7 KHz and ± 0.3 volts peak in the frequency band from 7 KHz to 400 MHz.

3. Under the conditions of a passive payload (resistive simulation of load), the ripple on the power supplied will not be greater than 0.8 volts peak-to-peak broadband (DC to 50 MHz): no discrete frequency will exceed 0.4 volts peak-to-peak. This condition applies at the modbody power interface only.

4. For the dedicated fuel cell operation, the Shuttle-generated ripple at the interface will not exceed 100 millivolts peak-to-peak (30 Hz to 10 MHz).

B. In-Flight DC Power Bus Transients: In-flight power bus transients shall not exceed the impulse equivalent of 300×10^{-6} volt seconds above or below normal line voltage. Peak transients will be limited to ± 50 volts measured line-to-line and between positive line and structure and will be limited to ± 30 volts when measured between return line and structure. Rise and fall times shall not be less than 1 microsecond.

C. Common-Mode Voltage: The common-mode voltage between electrical Spacelab/Orbiter bonding interfaces in the payload bay and the aft flight deck shall not exceed:

1. 0.3 volts peak-to-peak when measured in the time domain with an instrument bandwidth of at least 50 MHz. This is inclusive of a DC component which may exist in vehicle structural members.

2. 0.15 volts peak-to-peak for any discrete frequency between 30 Hz and 50 MHz.

3. $\pm 50 \times 10^{-6}$ voltseconds maximum transient excursions with rise and fall times not less than 1 microsecond; the peak shall not exceed 5 volts.

The common mode voltage values given above are defined as the voltage drop across two points of the Orbiter structure.

Note: The trunnion and keel attach fittings will be electrically isolated by Orbiter design.

4.7.1.2 Radiated Interference

The Shuttle-produced radiated fields environment shall be limited as follows:

A. AC magnetic fields shall be limited to less than 140 dB above 1 picotesla (30 Hz to 1 KHz), falling 40 dB per decade to 50 KHz. The DC field shall be less than 170 dB above 1 picotesla. The above are worst case values for locations near the Orbiter power buses at $Y_o = \pm 79$, $Z_o = 349$, $X_o =$ any value in the payload bay.

The above values of magnetic flux density are reduced in accordance with the following equation for separation from the power buses in the Y-Z plane.

$$\text{dB (reduction)} = 20 \log_{10} (57R^2)$$
 where P (meters) = radial separation in the Y-Z plane from the nearest nearest port or starboard power bus described by the above location coordinates.

For locations within 2.5 meters of the 576 or 1307 X_o locations, the value of R in the equation should be the separation from the $X_o = 576$ or $X_o = 1307$ locations in meters.

B. Electric fields along the payload bay centerline are defined in Figures 4.7-1 and 4.7-2 for unintentional emissions.

C. The electric field strengths produced by Orbiter-installed transmitters (defined in Figure 4.7-3) are worst case values in upper (+Z) quadrant of the payload envelope with doors open. Reduced levels can generally be expected in the lower levels of the payload bay.

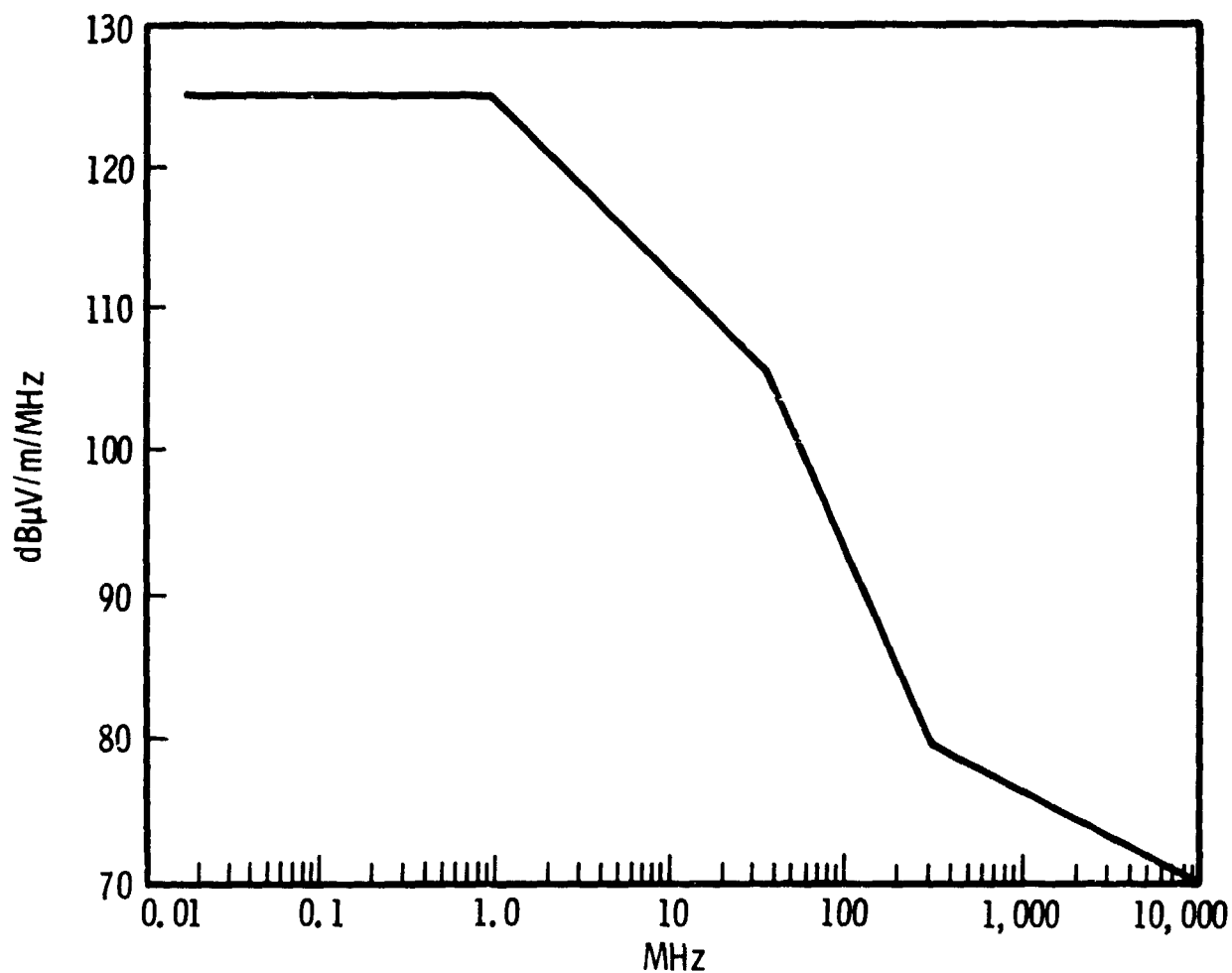


Figure 4.7-1. Shuttle-Produced Payload Bay Radiated Broadband Emissions

D. The electric field strengths produced by Orbiter-installed transmitters external to the bay are as follows:

Antenna	Transmitter power (W)	Spherical coverage (%)	Field strength (V/M)
Ku Band (Comm)	50	1.6	2181/R
Ku Band (Radar)	TBD	TBD	TBD
S Band Quad	100	72	42/R
S Band Hemi	10	40-50	6.9/R
S Band P/I	5	TBD	5.29/R
UHF (EVA)	0.25	85	0.27/R

where R is the distance in meters between the antenna and object in the electric field.

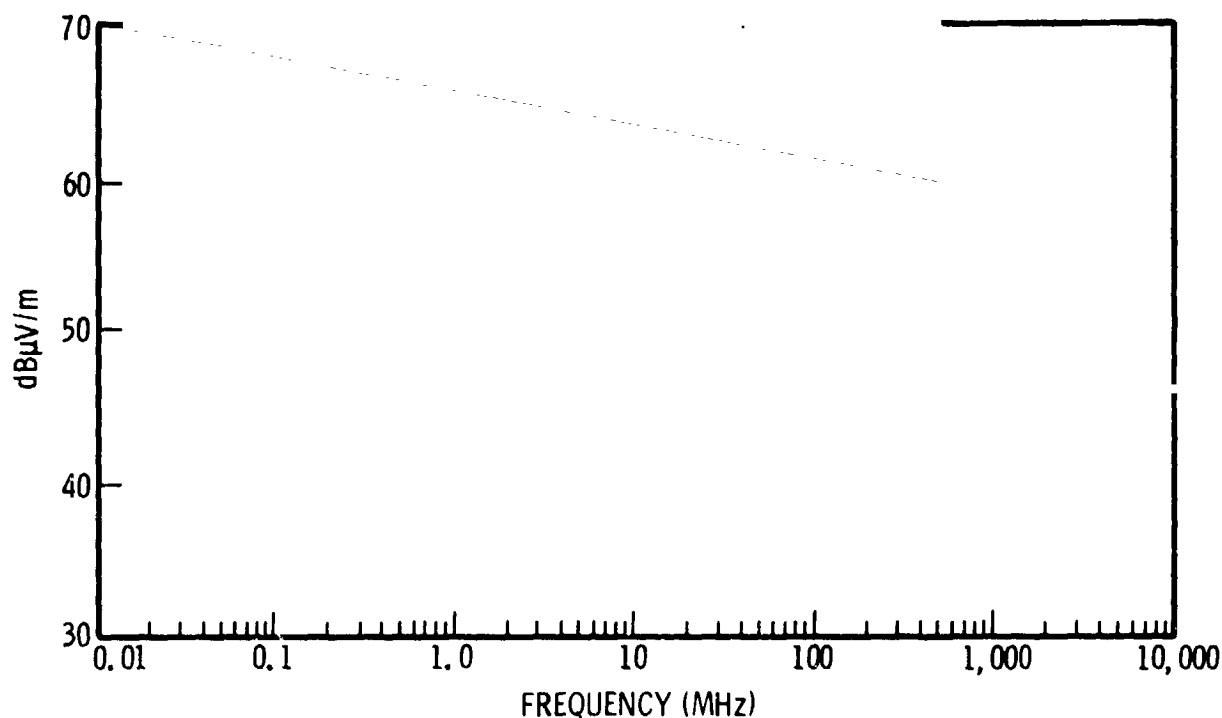


Figure 4.7-2. Shuttle-Produced Payload Bay Radiated Narrowband Emissions

E. Lightning-produced magnetic fields shall be limited to a peak level of 70 amperes/meter with a rise to peak value in 2 microseconds and fall to zero in 100 microseconds. The payload shall be designed so that a failure due to a lightning stroke shall not propagate to the Space Shuttle.

F. The design of the payload bay and payload bay doors shall preclude any electrostatic discharges.

4.7.2 Cargo-Produced Interference Environment

4.7.2.1 Cargo-Produced Conducted Noise

The cargo-generated conducted emission limits, applicable to all DC and AC power interfaces, shall be limited to the following:

A. DC Power:

1. The power line conducted emissions shall be limited to the levels indicated in Figure 4.7-4. These levels may be exceeded when operating from a dedicated fuel cell provided the radiated emissions limits of Paragraph 4.7.2.2 below are met; however, the Shuttle power bus ripple voltages shall not be applicable.

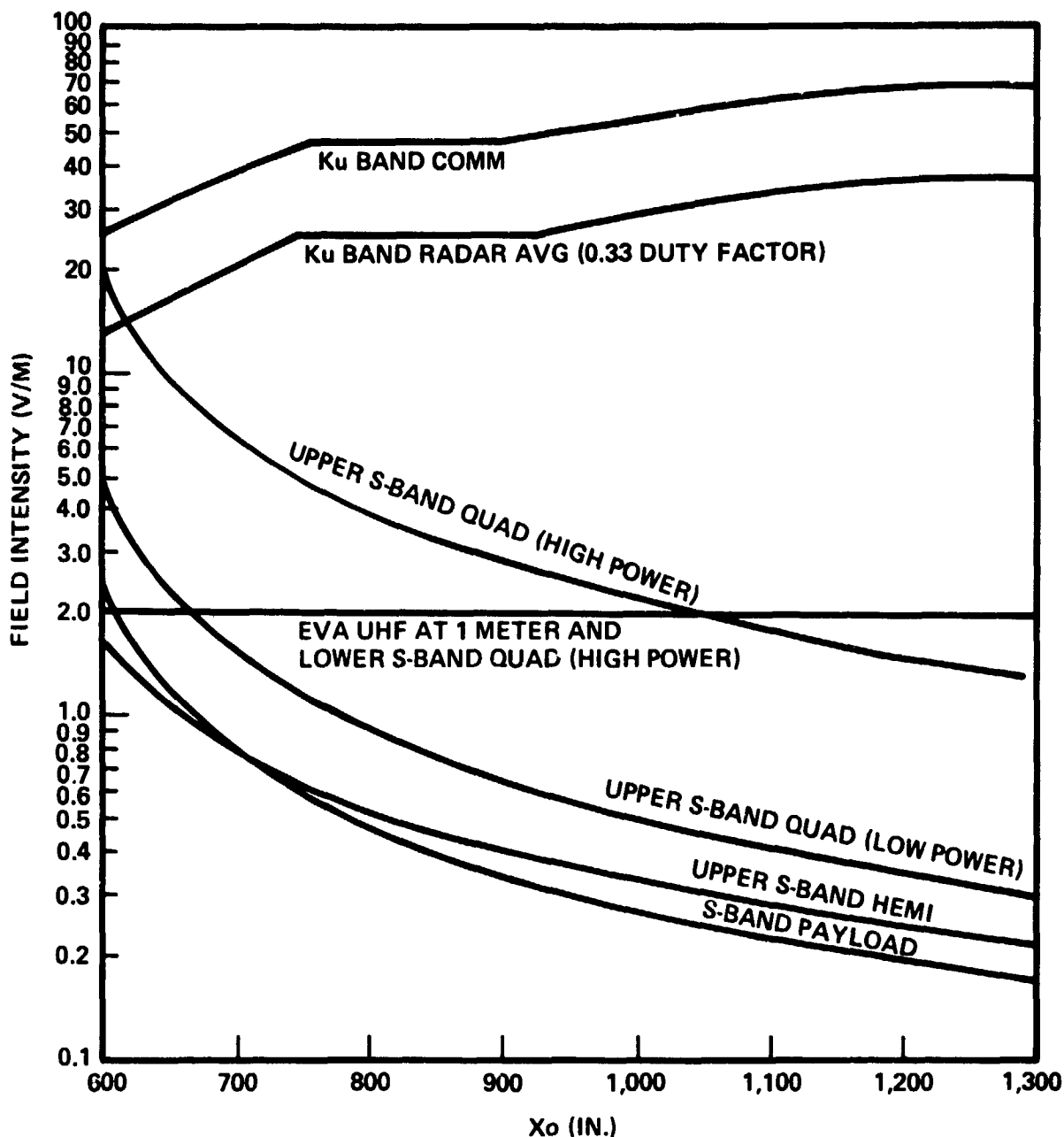


Figure 4.7-3. Maximum Field Intensities on Payload Envelope

2. The cargo-generated spikes produced on DC power lines by switching or other operations shall not exceed the limits defined in Figure 4.7-5 for normal operation and Figure 4.7-6 for abnormal operation when fed from a source impedance within the limits defined in Figures 4.7-7 and 4.7-8. Rise and fall times shall be greater than 1.0 microsecond.

B. AC Power:

1. The AC-power-line-conducted emissions of the Cargo AFD equipment shall not exceed the limits defined in Figure 4.7-5.

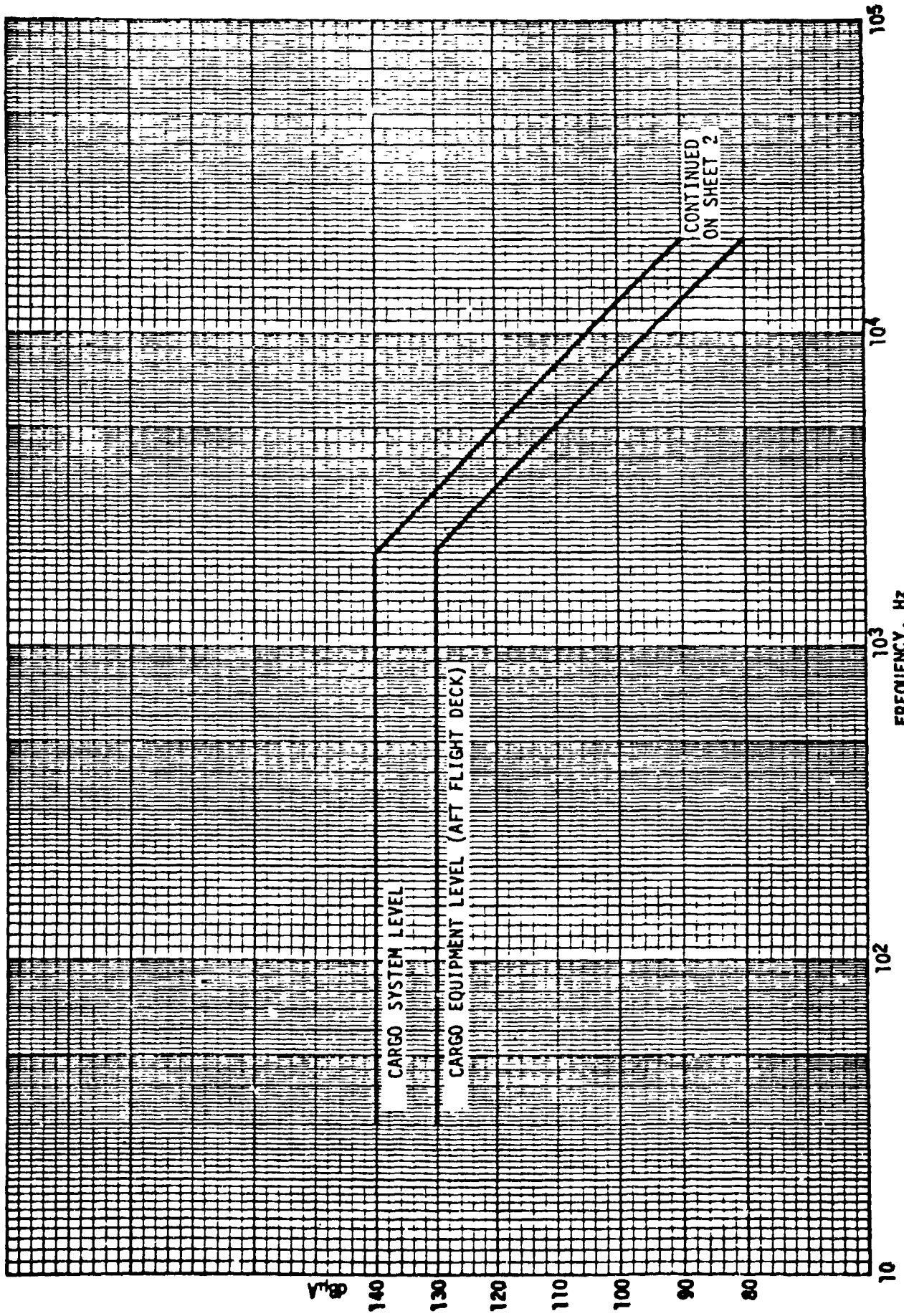


Figure 4.7-4. Cargo Allowable Conducted Narrowband Emissions (Sheet 1 of 2)

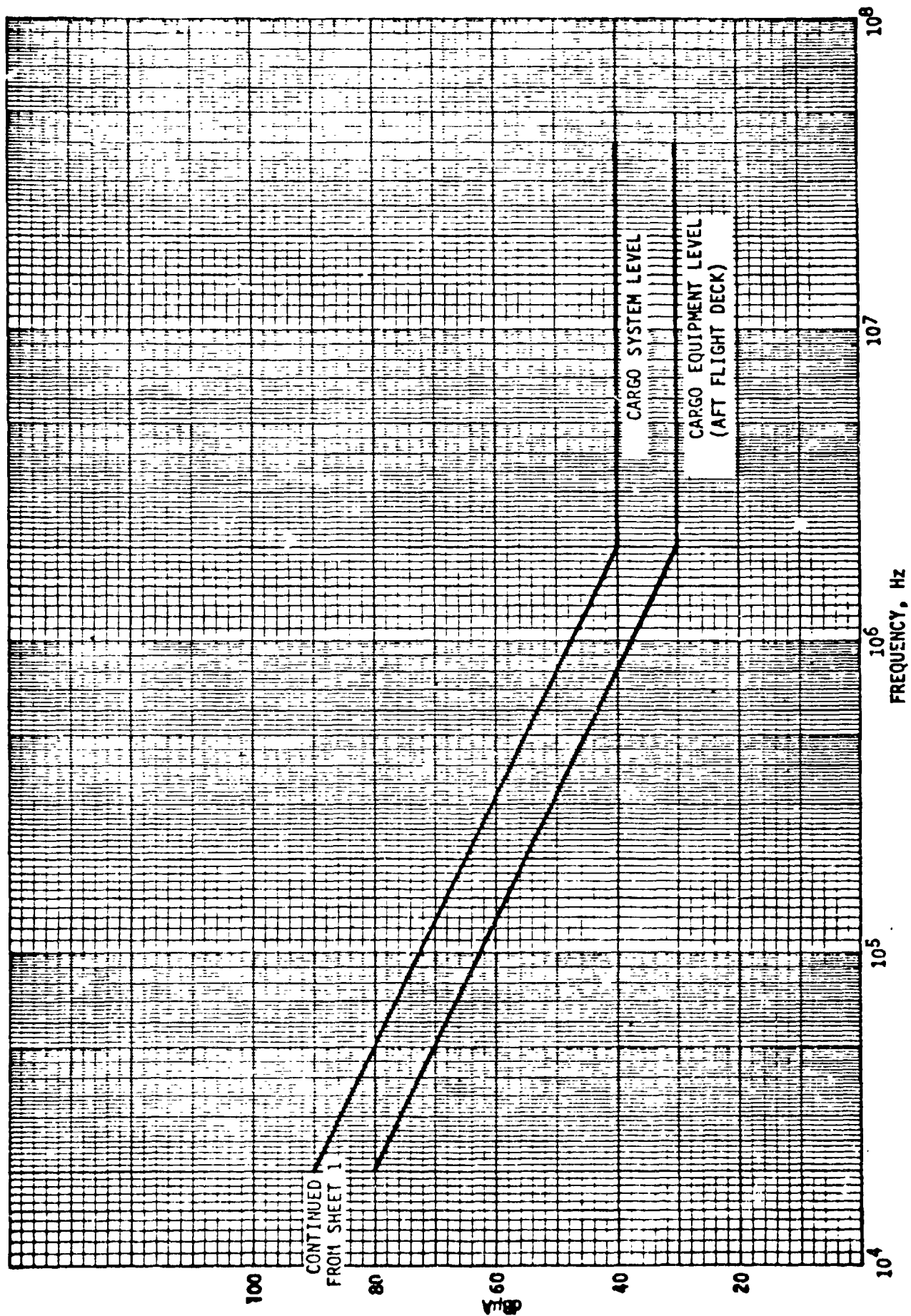


Figure 4.7-4. Cargo Allowable Conducted Narrowband Emissions (Sheet 2 of 2)

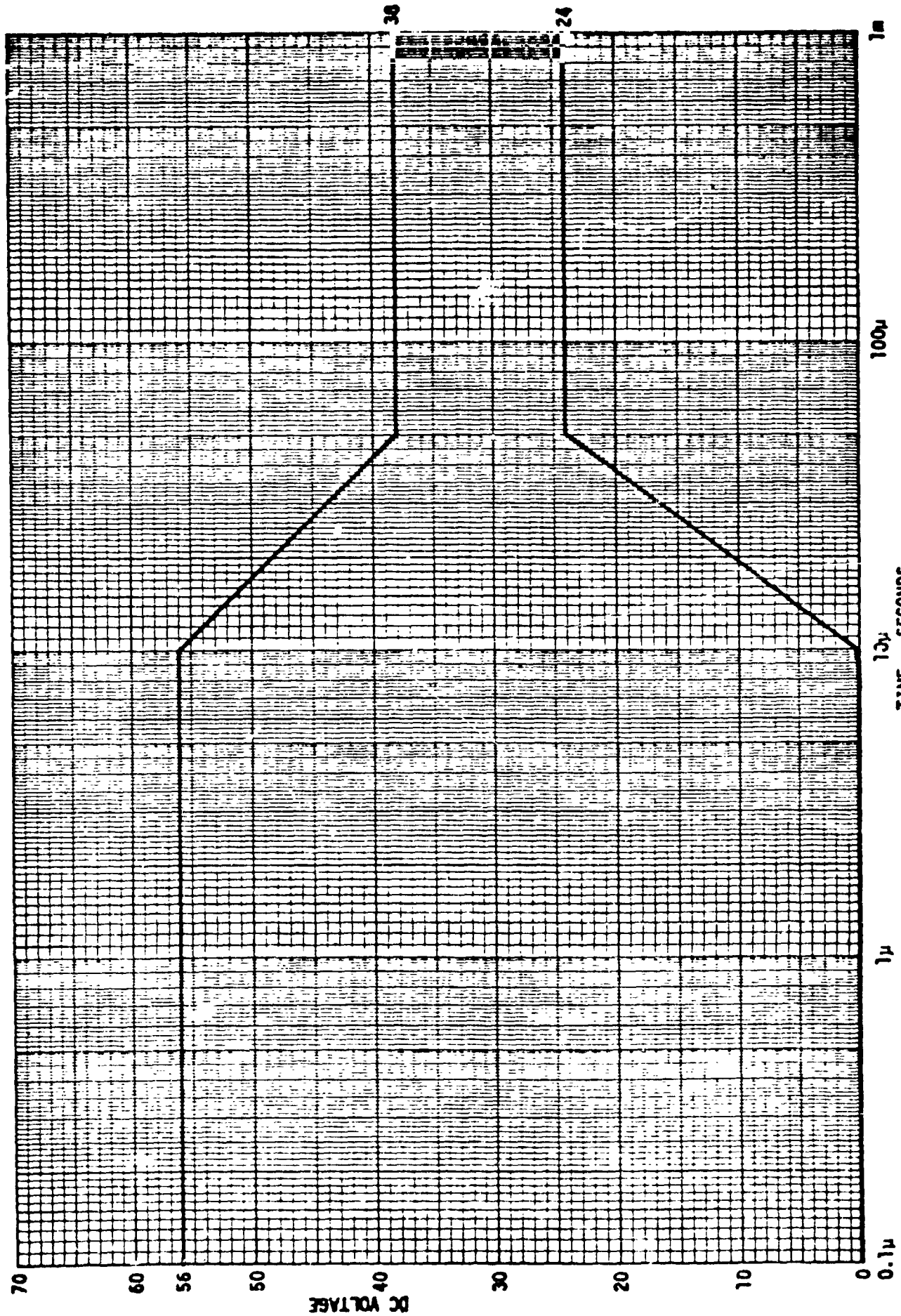


Figure 4.7.5. Envelope of Cargo Allowed Spikes on DC Power Buses for Normal Electrical System Operation

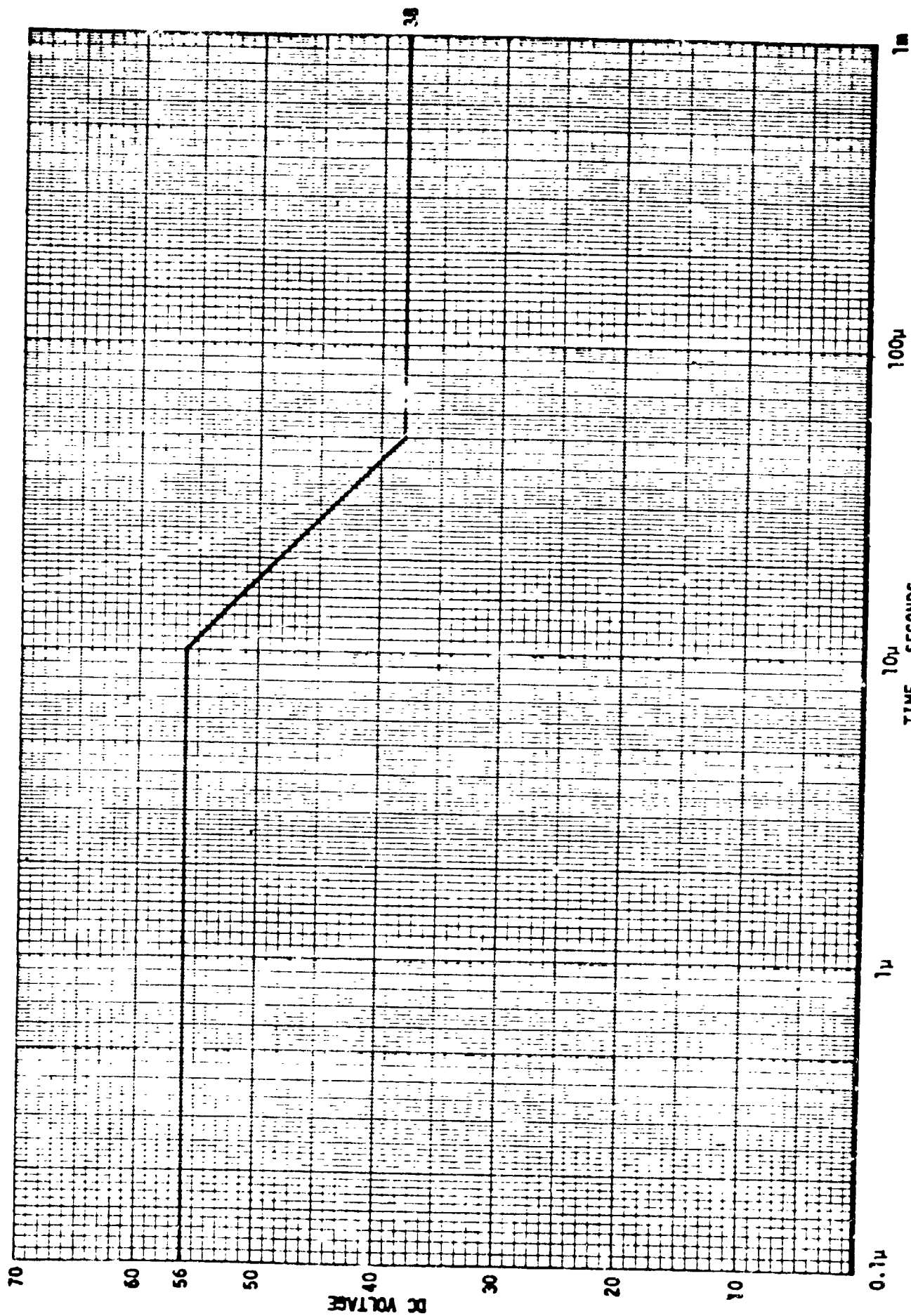


Figure 4.7-6. Envelope of Cargo Allowed Spikes on DC Power Busses for Abnormal Electrical System Operation

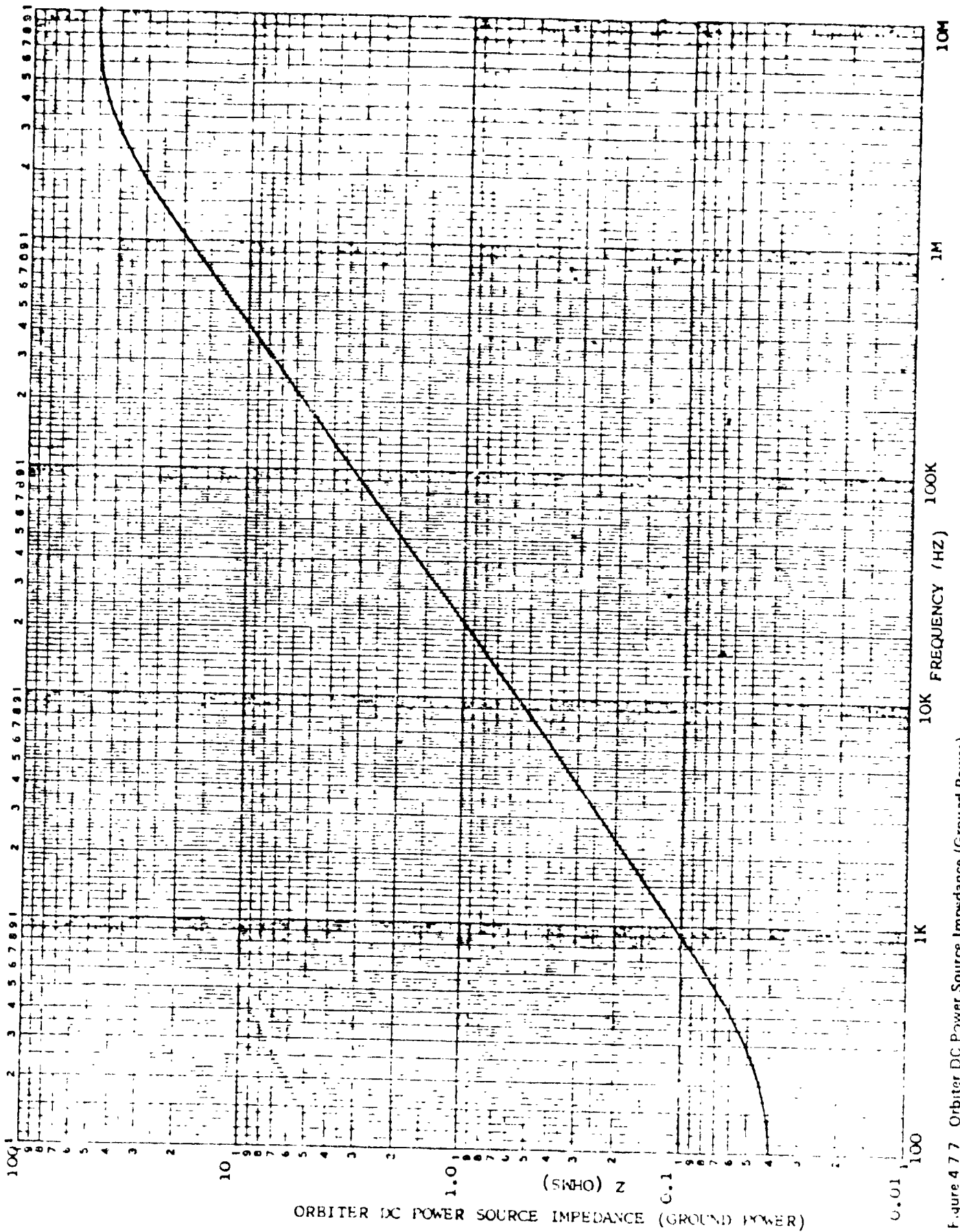


Figure 4.7.7 Orbiter DC Power Source Impedance (Ground Power)

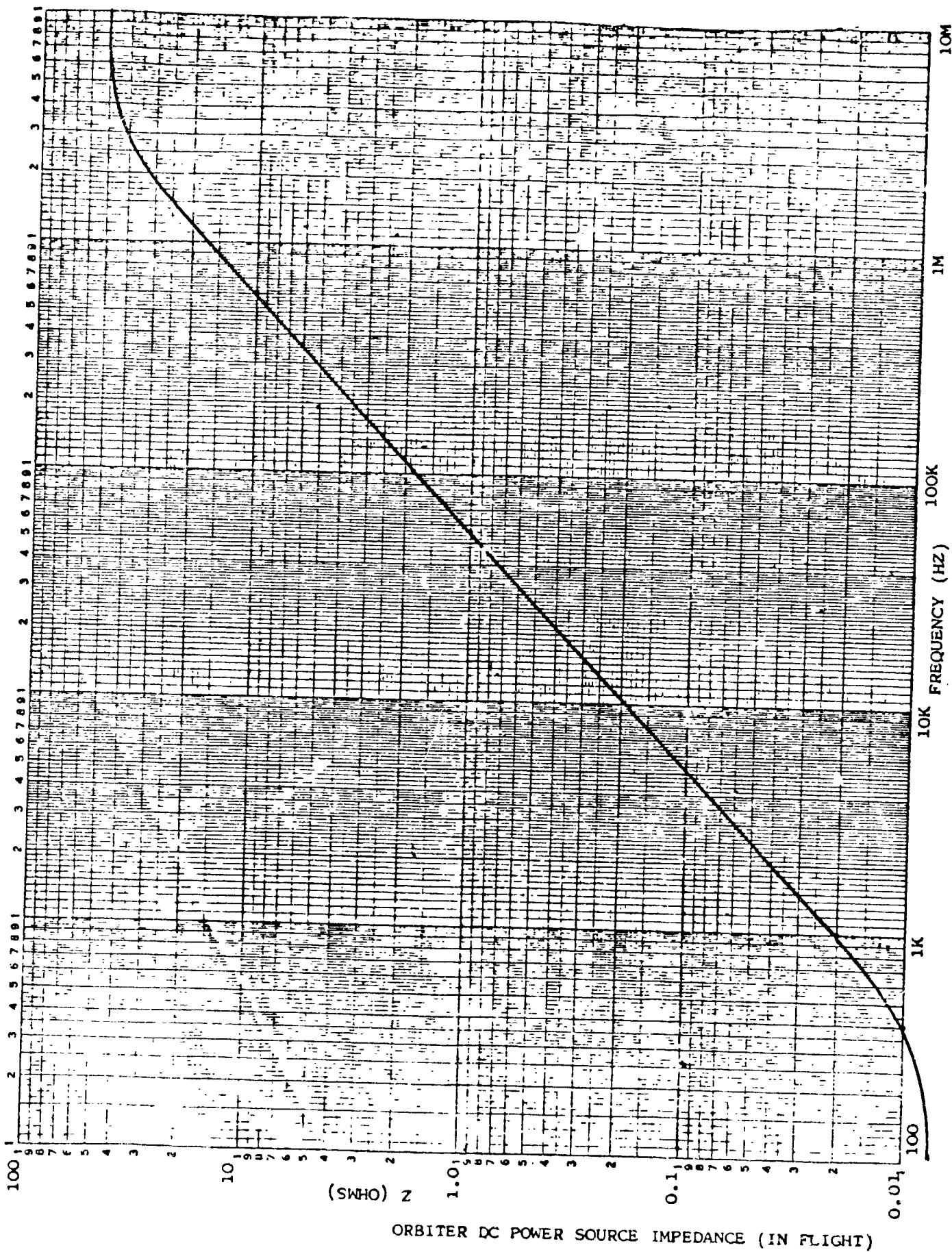


Fig. 4.7-8. Orbiter DC Power Source Impedance (In-Flight)

2. AC power-bus transient spikes generated by the Cargo AFD equipment shall not exceed the limits defined in Figure 4.7-9 for both normal and abnormal operations when fed from a source impedance not greater than 10 ohms. Peak spikes below 10 microseconds duration, for normal electric system operations, shall be limited to 60 volts superimposed on the 400 Hz sine wave. Rise and fall times shall be greater than 1.0 microseconds.

4.7.2.2 Cargo--Produced Radiated Fields

The cargo-produced radiated fields shall be limited as follows:

A. The generated AC magnetic fields (applies at a distance of 1 meter from any payload equipment) shall not exceed 130 dB above 1 picotesla (30 Hz to 2 KHz) falling 40 dB per decade to 50 KHz.

B. The radiated electric fields shall not exceed the levels defined in Figures 4.7-10 and 4.7-11 except that the broadband emissions for cargo equipment in the payload bay shall be limited to 70 dB above 1 microvolt/meter/MHz in the frequency range of 1770 MHz to 2300 MHz. Narrowband emissions shall be limited to 25 dB above 1 microvolt/meter from 1770 MHz to 2300 MHz, excluding any payload intentional transmitters.

C. Allowable levels of radiation from payload transmitter antenna systems are shown in Figure 4.7-12. These levels are established with respect to levels incident on Orbiter equipment and should not be construed to limit radiation at higher levels with a directional antenna through open payload bay doors.

D. Electrostatic discharges shall not occur within the payload bay other than those isolated from the AFD and payload bay gaseous environment (hydrogen-oxygen mixture) and shielded by the cargo to satisfy the requirements of Subparagraphs A and B above.

4.7.3 Ground Radar--Produced Radiated Interference

Electric field intensities of 22V/M maximum in the Radar Band of the electromagnetic spectrum are indicated to exist.

4.8 RCS PLUME ENVIRONMENT

TBD

4.9 RELATIVE DEFLECTIONS

TBD

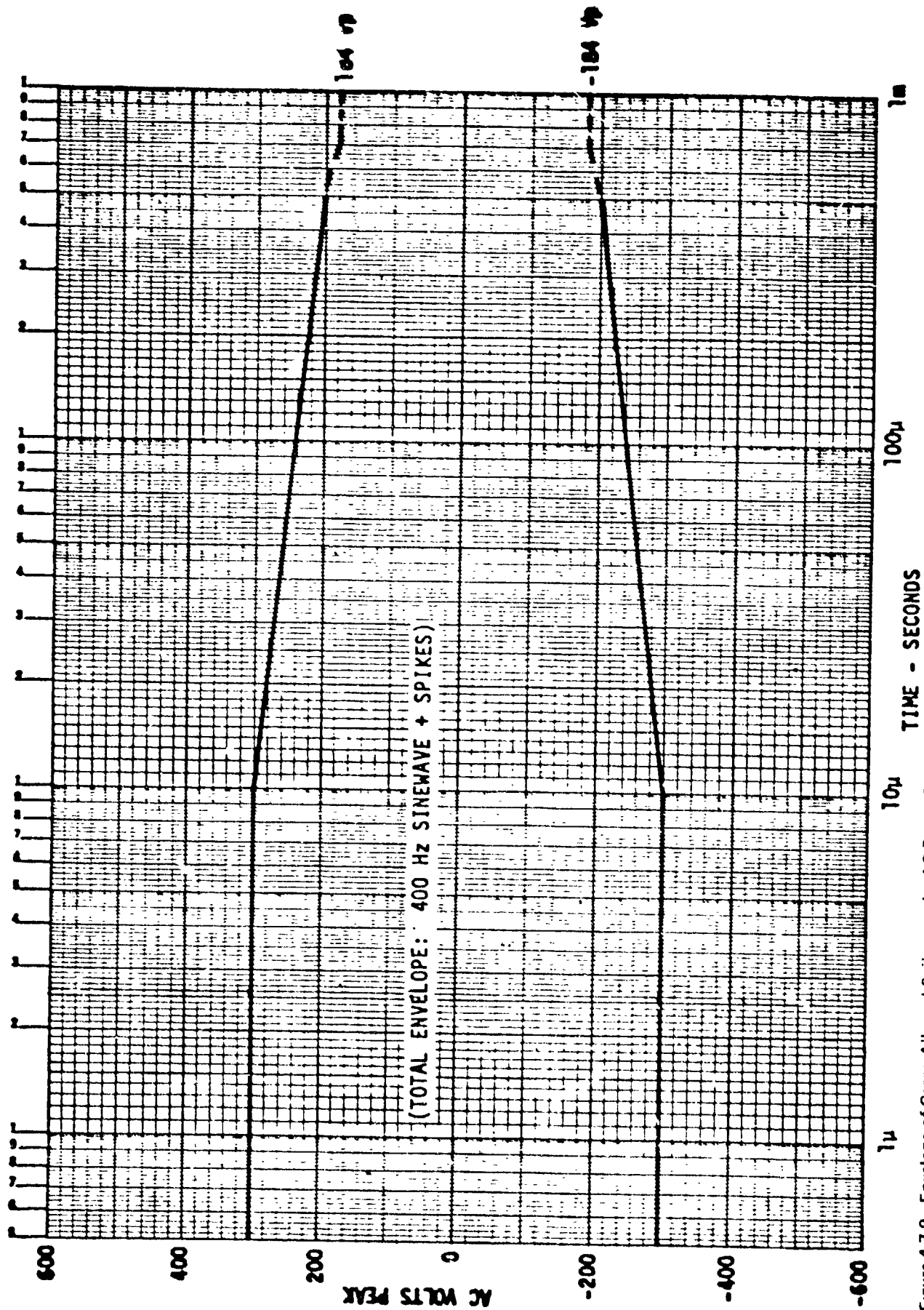


Figure 4.7.9. Envelope of Cargo Allowed Spikes on the AC Power Bus

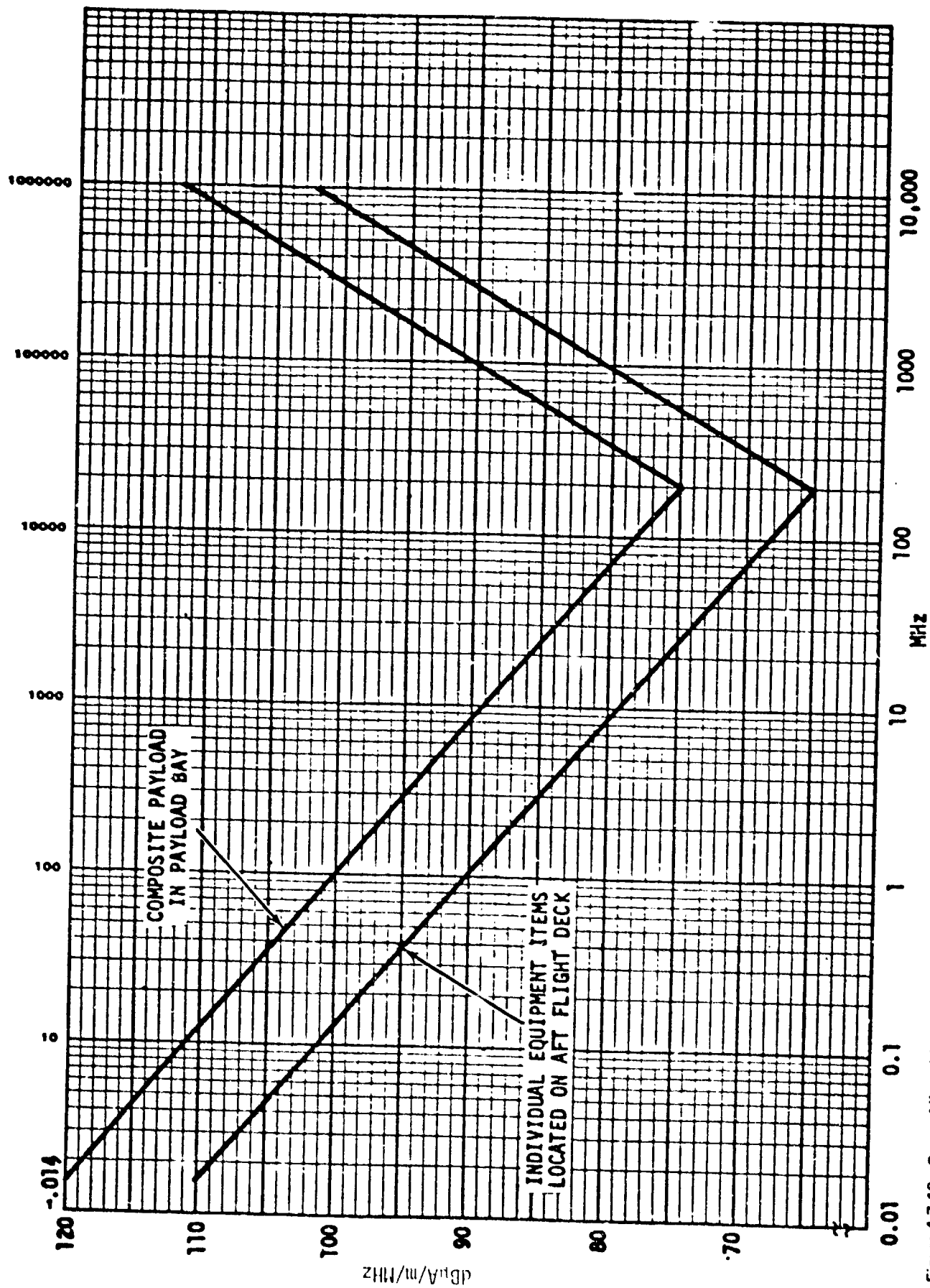


Figure 4.7-10. Cargo Allowable Radiated Broadband Emissions

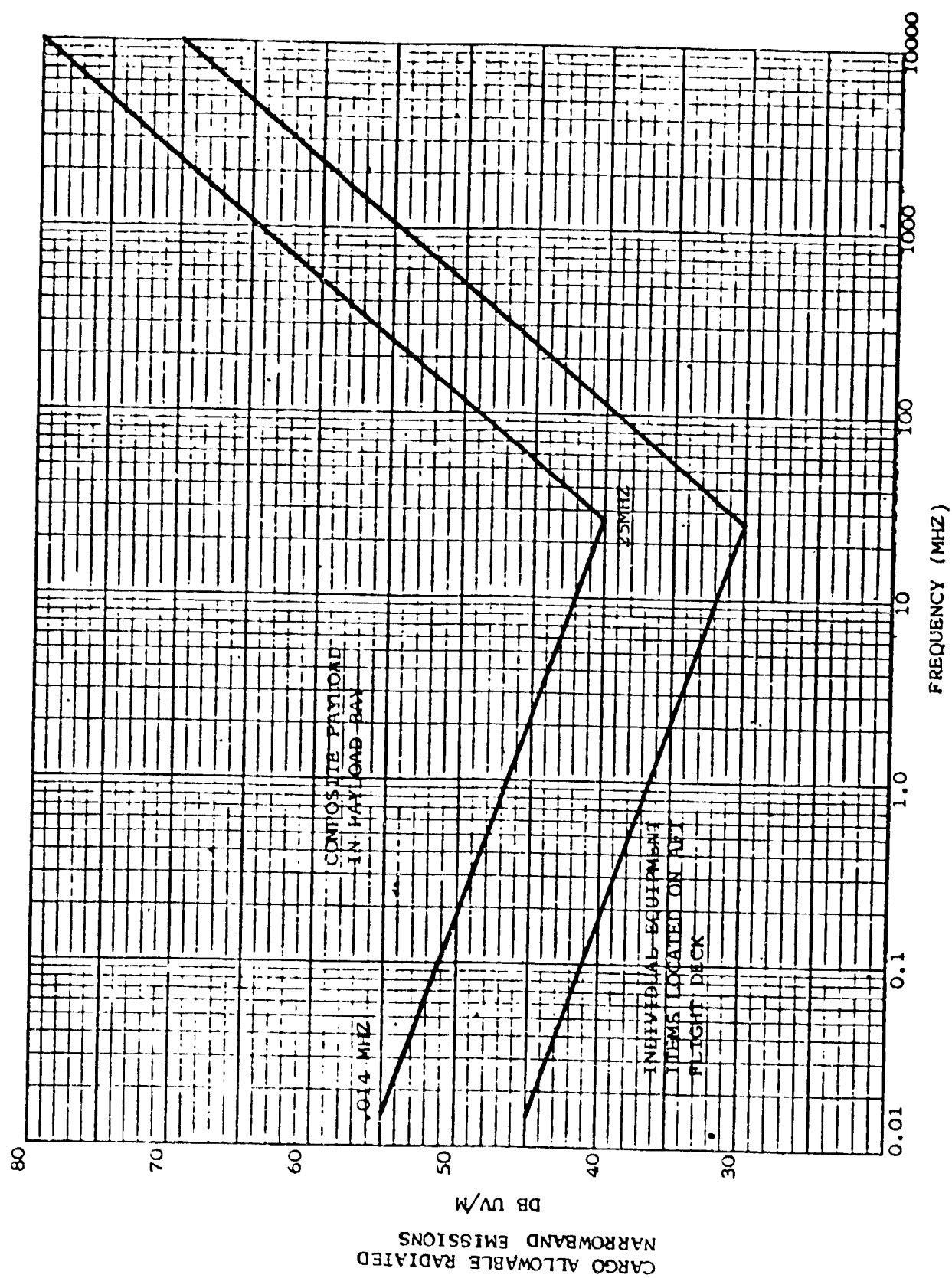


Figure 4.7-11. Cargo Allowable Radiated Narrowband Emissions

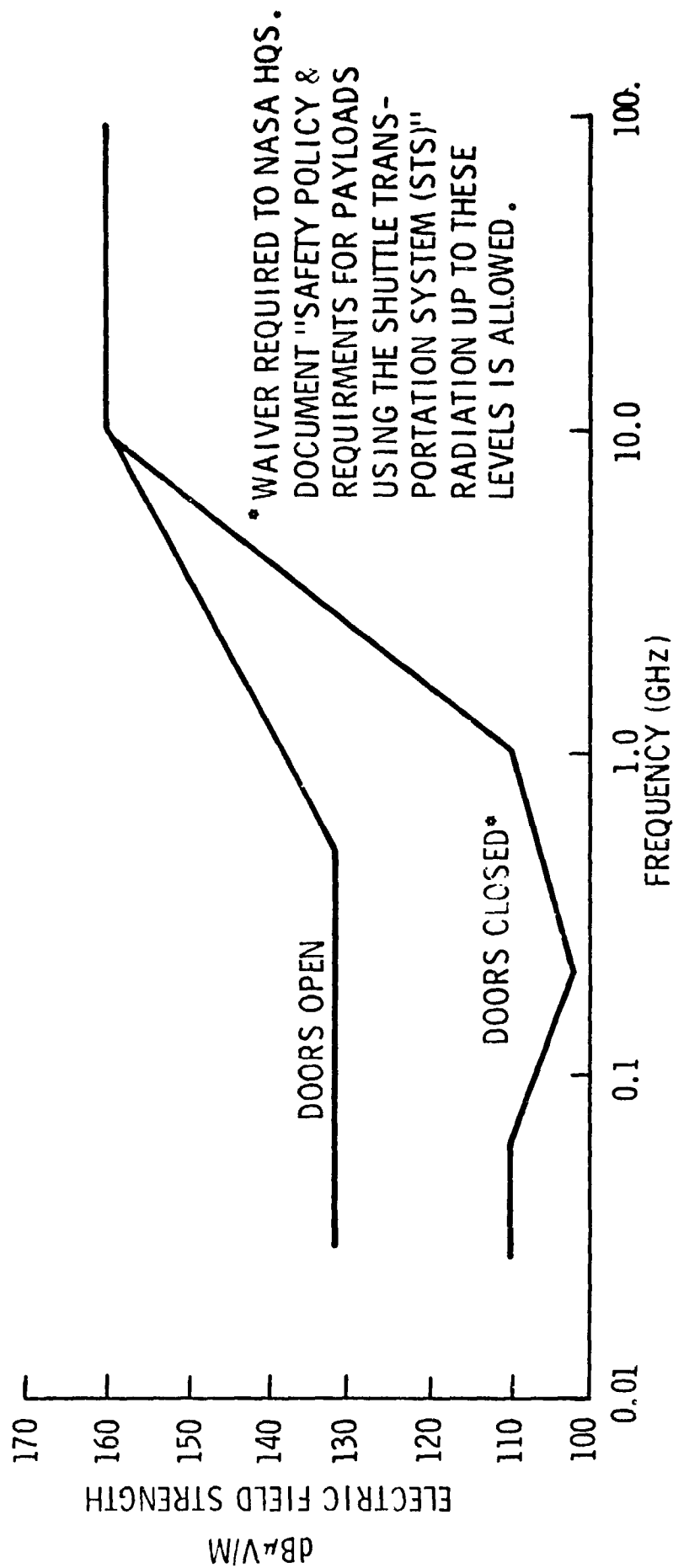


Figure 4.7-12. Allowable Field Strength From Cargo Transmitters